GPM Timeline Inhibits for I&T Processing

Shirley Dion
GPM Safety/ASRC

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Agenda

- Scope of Discussion
- Motivation for Creation of the Tool
- Definition of Terms
- GPM Overview
- Tool Development Process Steps
  - Step 1 Define Inhibits and controls
  - Step 2 Define I&T testing
  - Step 3 Determine inhibit status during each test
  - Step 4 Determine software criticality
- Unique Hazard Report Controls and Verifications for Software
- Summary

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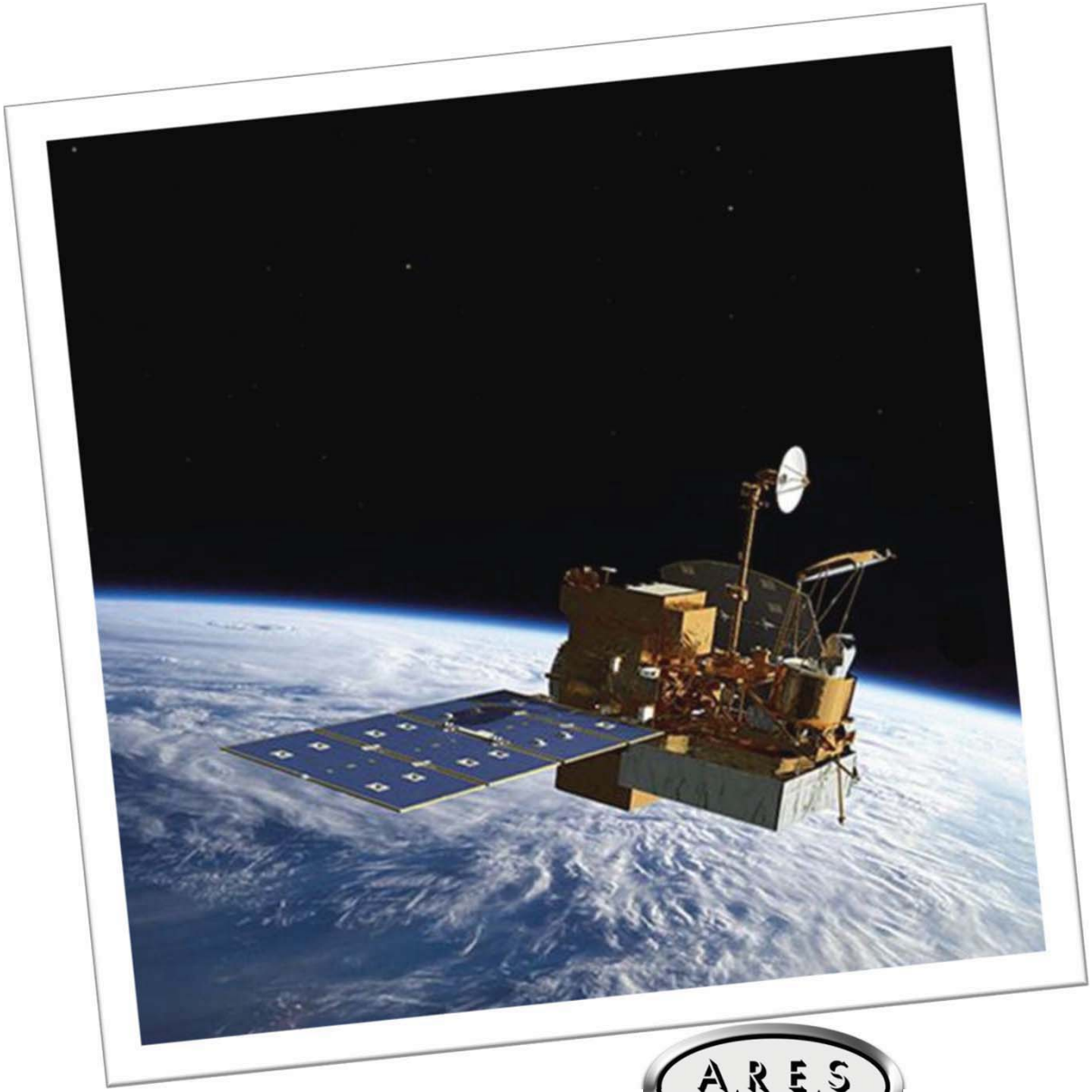
Scope of Discussion

Development of S/C inhibit tracking for GPM during I&T at GSFC and at the range



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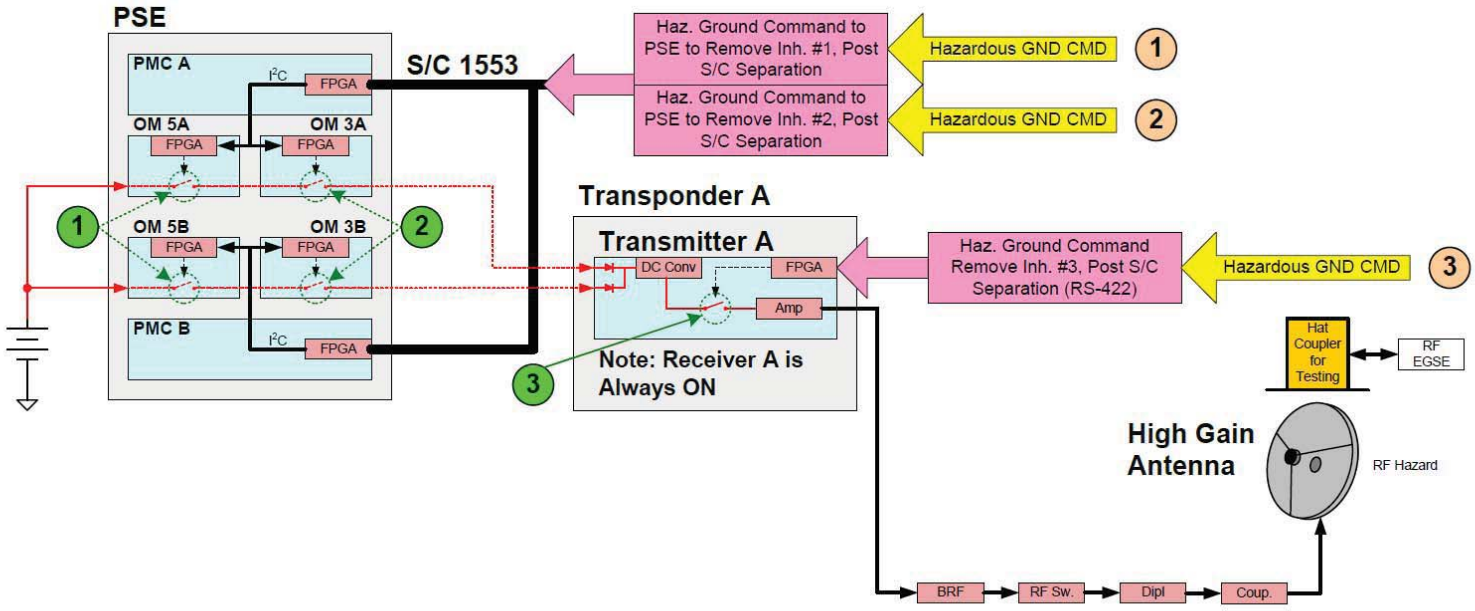
Motivation for Creation of the Tool

1. How and why did this come up on GPM?
2. Why was developing this process/tool important?

Definition of Terms

1. Terms
   - Inhibits
   - Controls
   - Critical Software Commands/Controls
   - Fault (Failure) tolerance
   - Design for Minimum Risk

Definition of Terms



1. **Inhibits** *An independent and verifiable mechanical and/or electrical device that prevents a hazardous event from occurring; the device has direct control and is not the monitor of such a device. NPR 8715.7A) (Green circles)*
2. **Controls** *Hardware or software that affects the operation of an inhibit. (Shirley's definition). (Tan circles)*
3. **Critical Software commands** -*A command that either removes (and/or activates) a safety inhibit or creates a hazardous condition. (NPR 8715.3C, App B) (yellow arrows)*
4. **Fault (Failure) tolerance** *The ability to sustain a certain number of failures and still retain capability. (NPR 8705.2B, NPR 8715.3C App B)*
5. **Design for Minimum Risk** *Structural members, pressure vessels, pressurized lines/valves, pyrotechnics, material compatibility, some mechanisms, flammability, etc., where fault tolerance design is not practically possible, shall be controlled by design standards or other established organizations (design using robust design margins and safety factors)*

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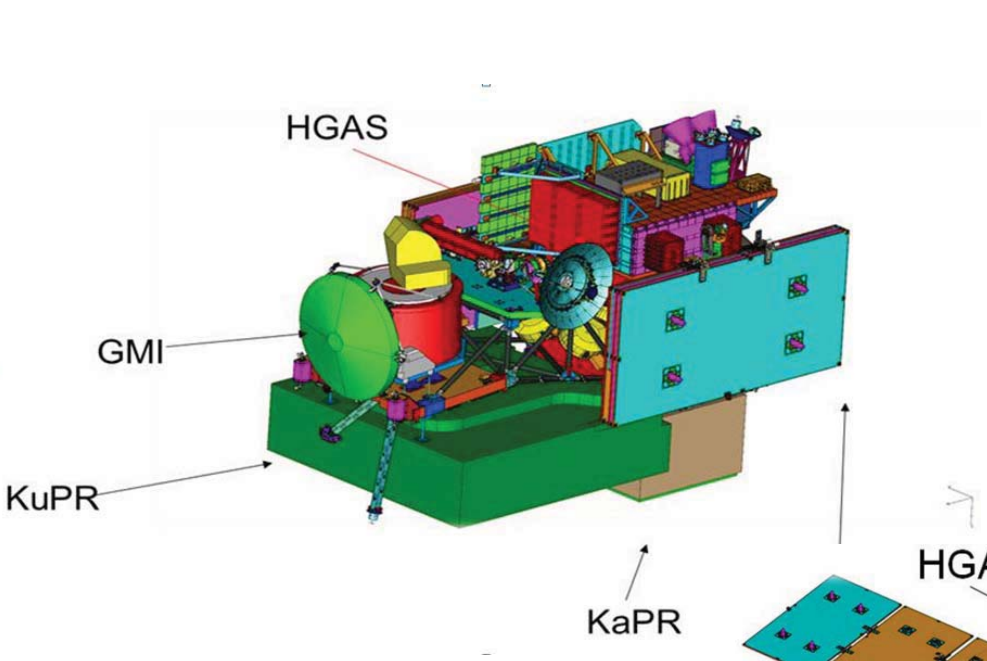
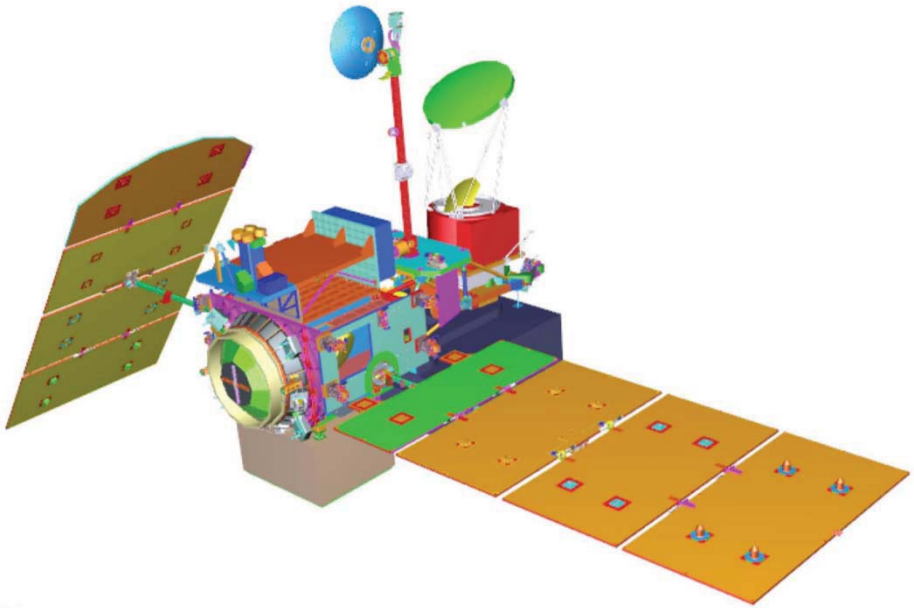
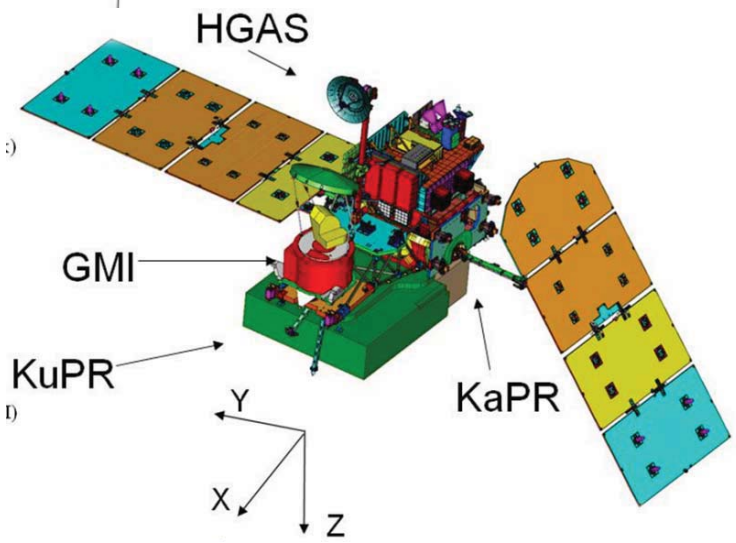
GPM Overview

1. What does GPM do?
2. How many instruments are there?

GPM Overview







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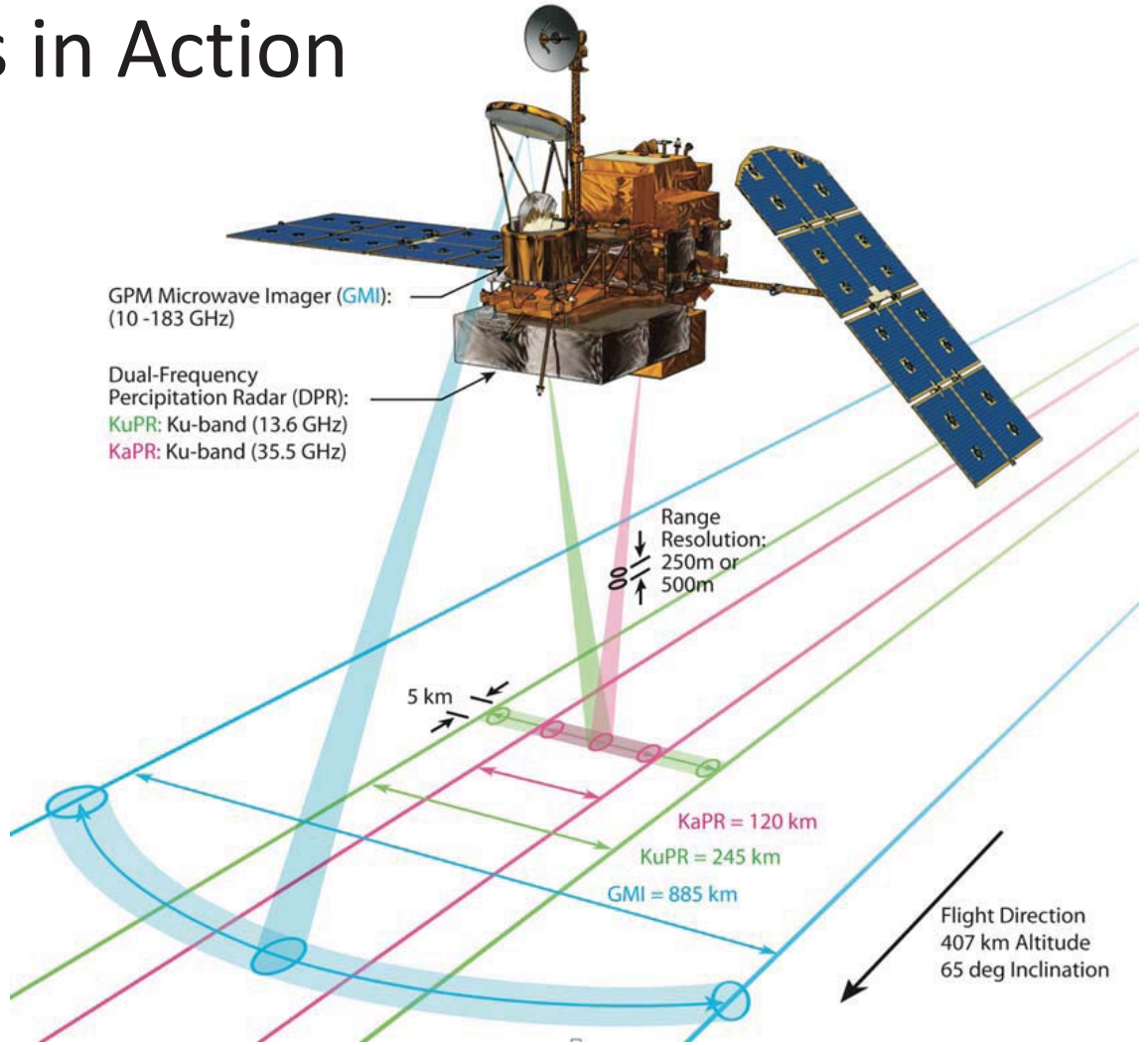
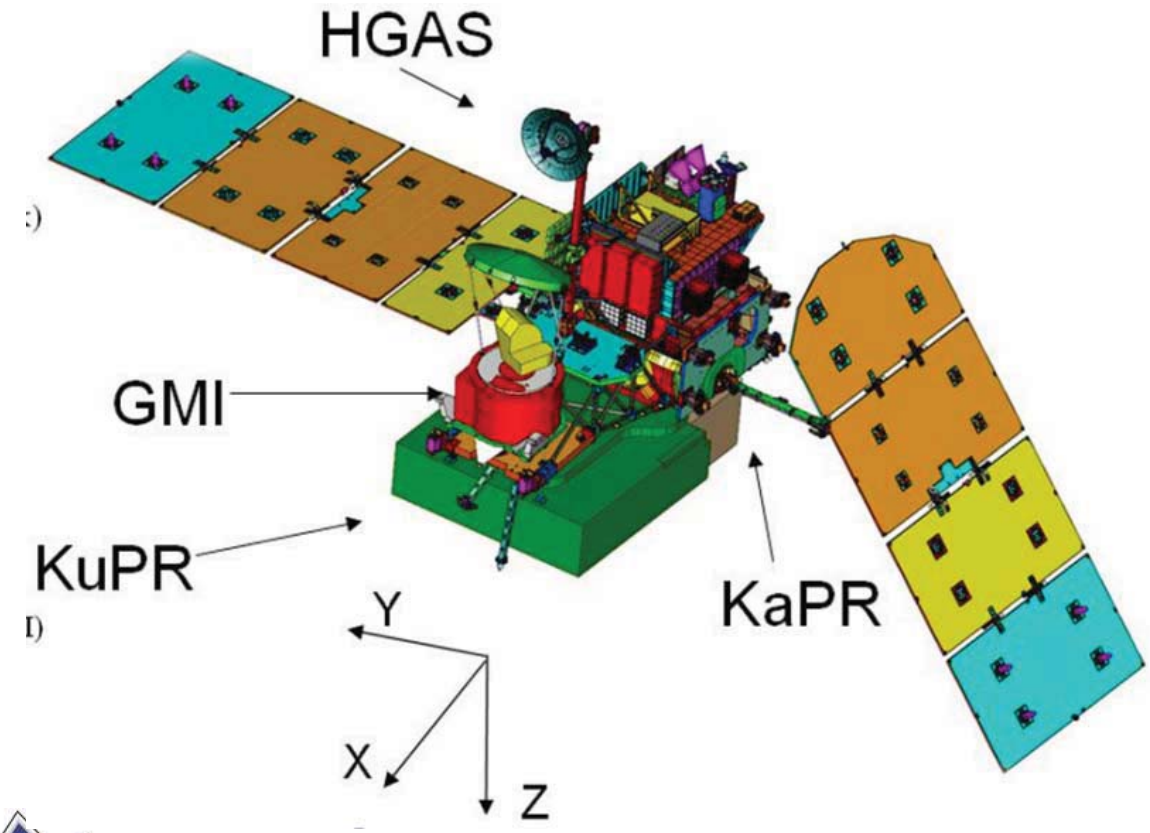
GPM Overview

Instruments in Action



GPM Overview

What are the hazards?



GPM Overview

- What are the hazards?
  - 1 Deployables
    - HGAS –High Gain Antenna System
    - SA Solar arrays
    - GMI Instrument (GPM Microwave Imager)
  - 2 RF
    - S/C transmitter
    - DPR (Duel Precipitation Radar) 2 Radars at GHZ 13ish 35 ish
  - 3 Fuel System
    - Propulsion

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GPM Overview

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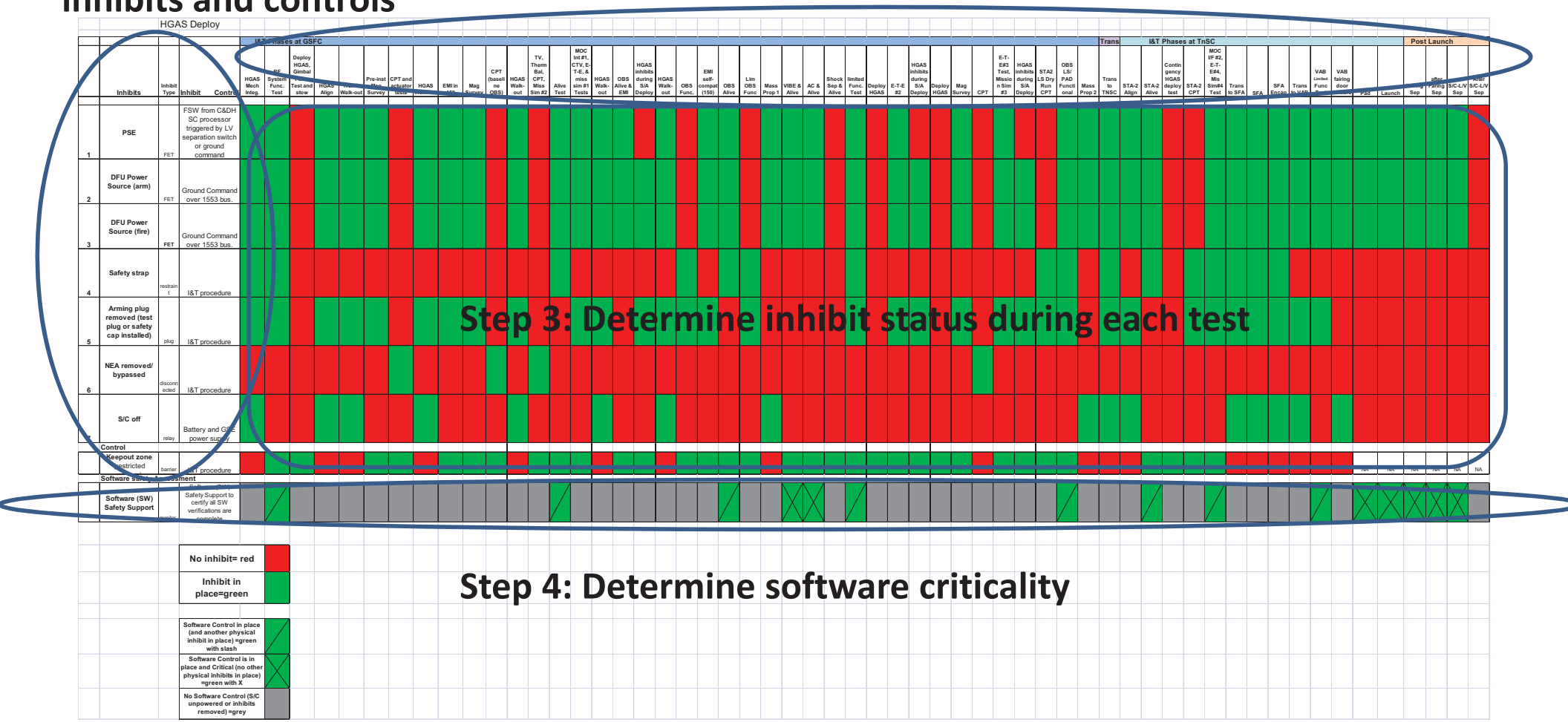
Tool Development Process Steps

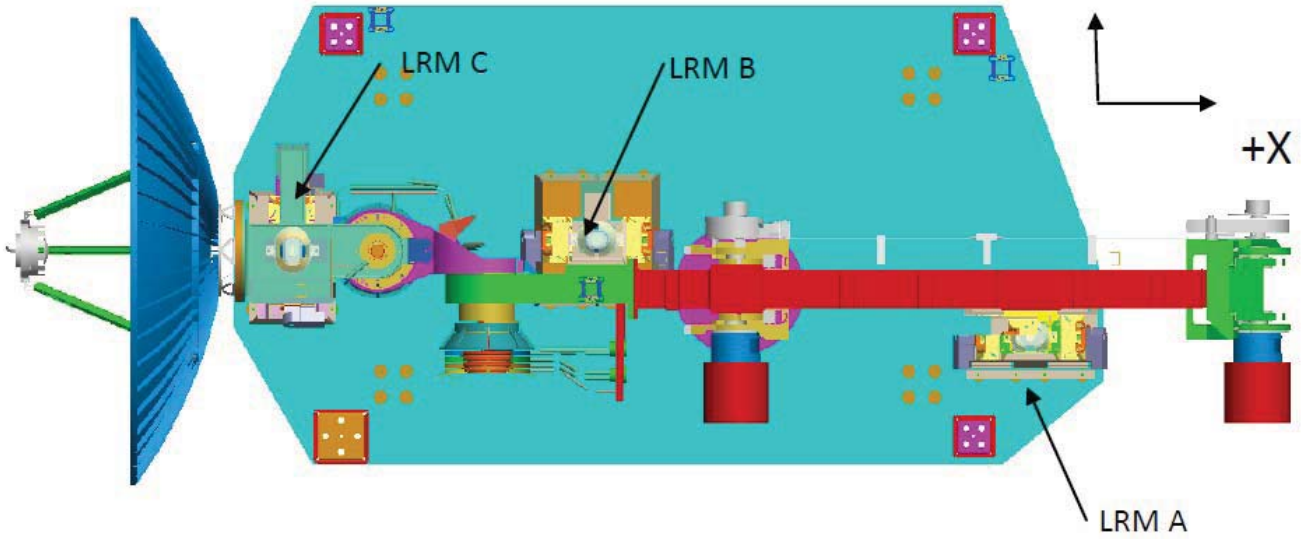
Step 1: Define inhibits and controls

Step 2: Define I&T Testing



Step1 Define inhibits and controls

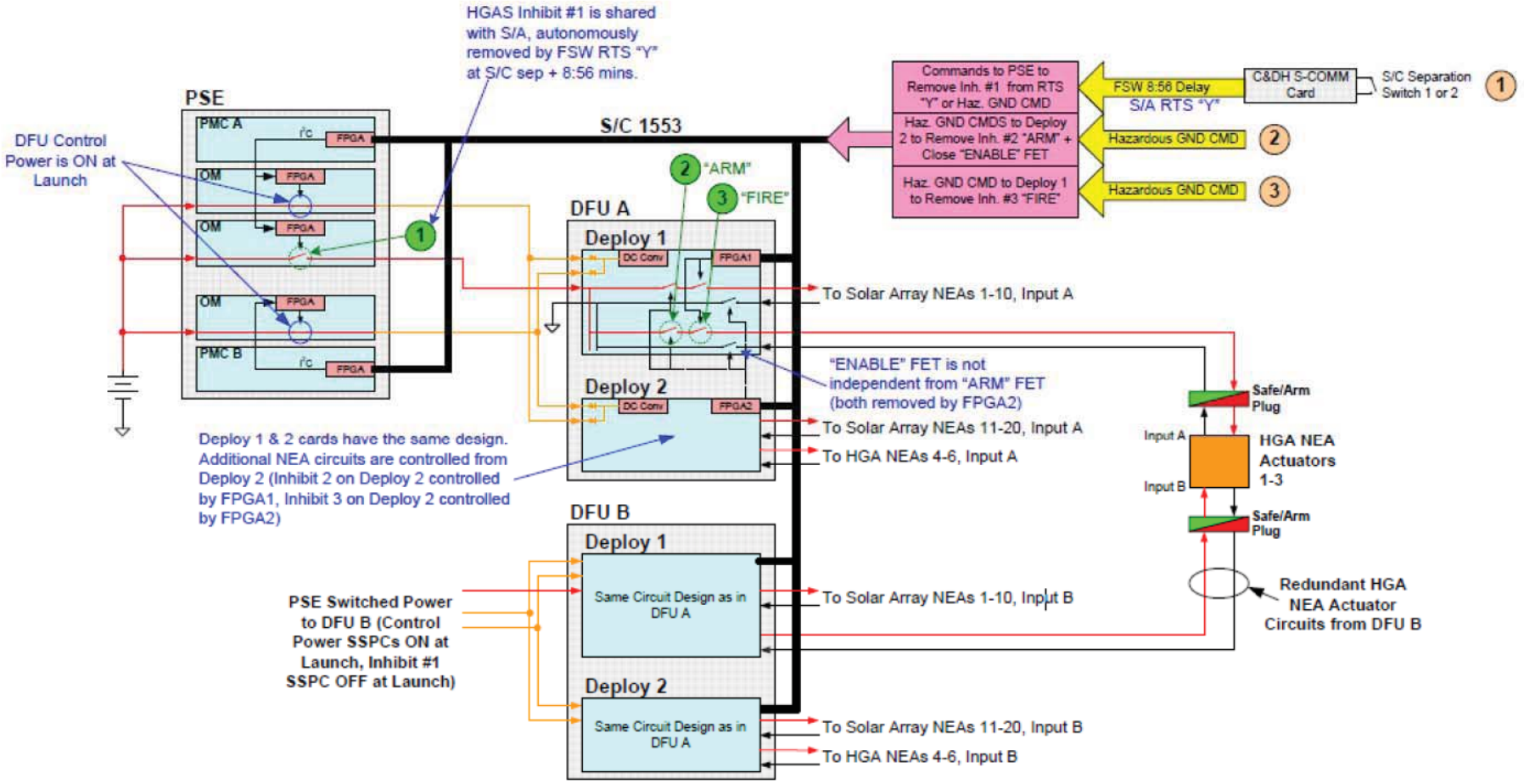
HGAS stowed



LRM- Launch Restraint Mechanism
HGAS-High Gain Antenna System

Step1 Define inhibits and controls

HGAS Electrical Inhibits

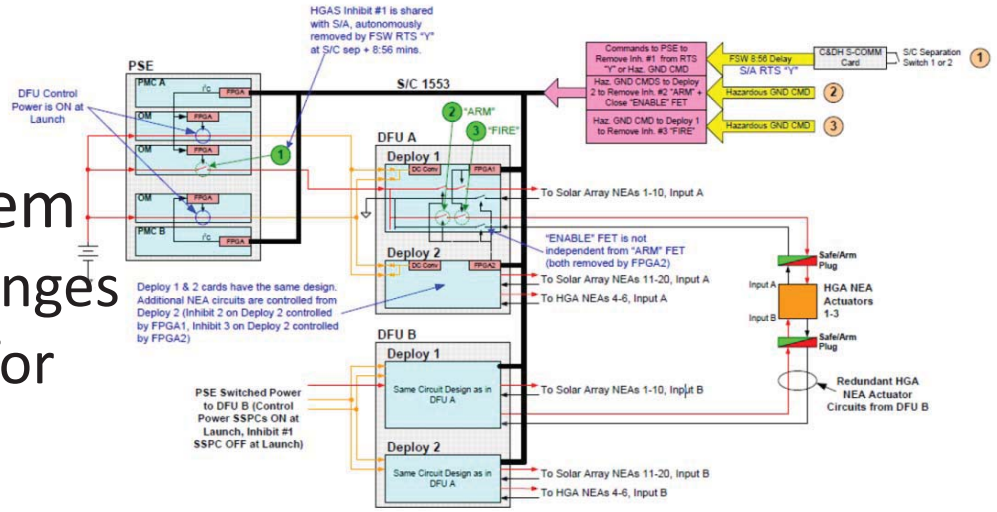


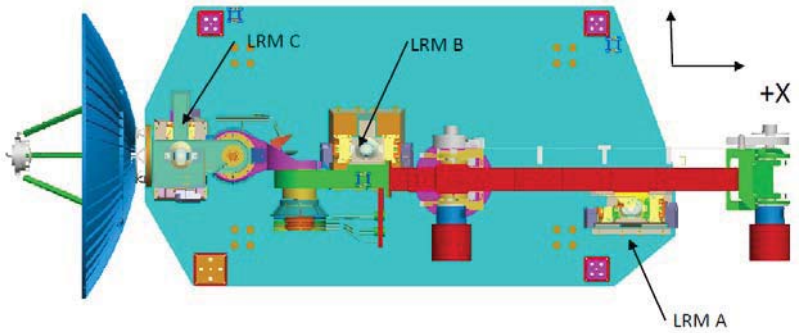
DFU-Deployment Firing Unit
PSE- Power Supply Electronics
NEA-Non-Explosive Actuators

Step1 Define inhibits and controls

HGAS Inhibits and Controls

- HGAS –High Gain Antenna System
  - Mechanically (3) Deployment hinges
  - Electrically it is 2-fault tolerant for each hinge
  - Inhibits include:
    1. FET in Power Systems Electronics
    2. 1st FET in Deployment Firing Unit
    3. 2nd FET in Deployment Firing Unit
    4. Power relay switch off
    5. Safety strap/tie
    6. Arming plug removed
    7. NEA's are either removed or by-passed
    8. Keepout zone- (Not an inhibits but is a control)





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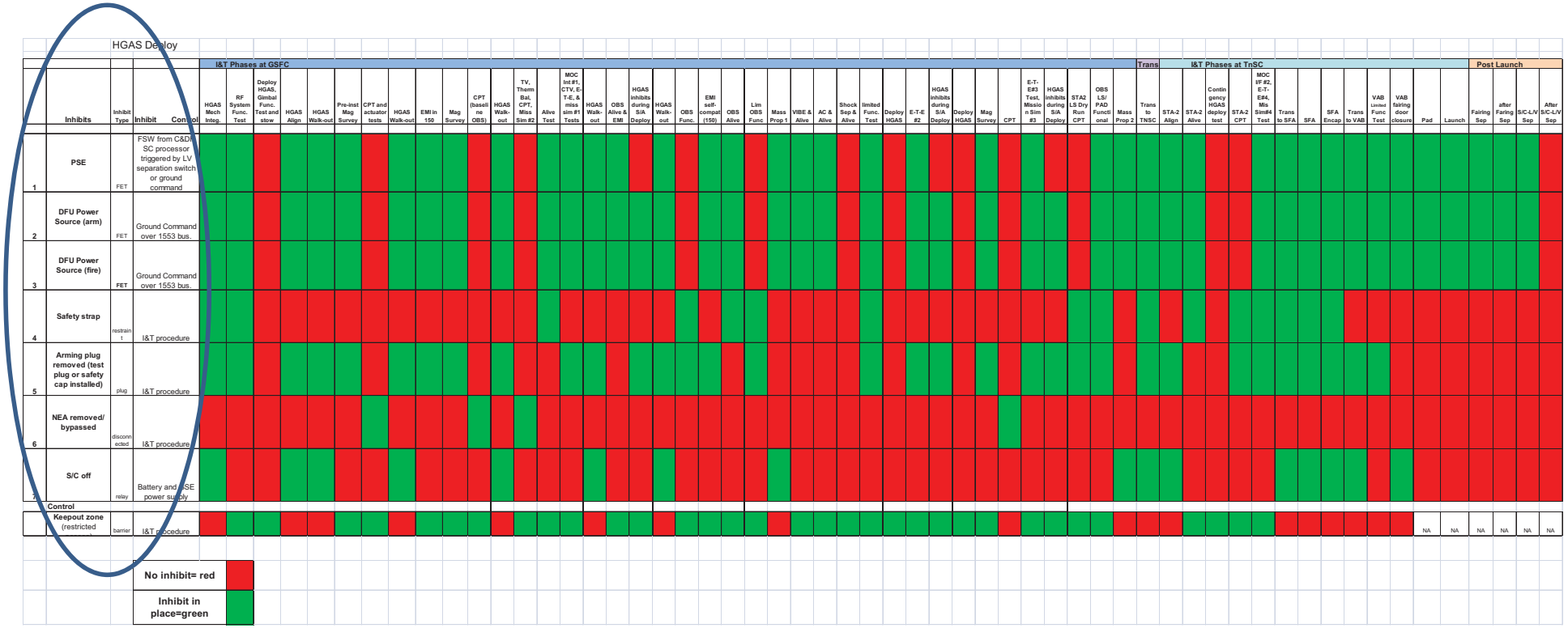
Step1 Define inhibits and controls



Step1 Define inhibits and controls

	Inhibits	Inhibit Type	Inhibit Control
1	PSE	FET	FSW from C&DH SC processor triggered by LV separation switch or ground command (same as SA)
2	DFU Power Source (arm)	FET	Ground Command over 1553 bus to DFU.
3	DFU Power Source (fire)	FET	Ground Command over 1553 bus to DFU.
4	Safety strap	restraint	I&T procedure
5	Arming plug removed (test plug or safety cap installed)	plug	I&T procedure
6	NEA removed/ bypassed	disconnected	I&T procedure
7	S/C off	relay	Battery and GSE power supply
	Control		
	Keepout zone (restricted access)	barrier	I&T procedure

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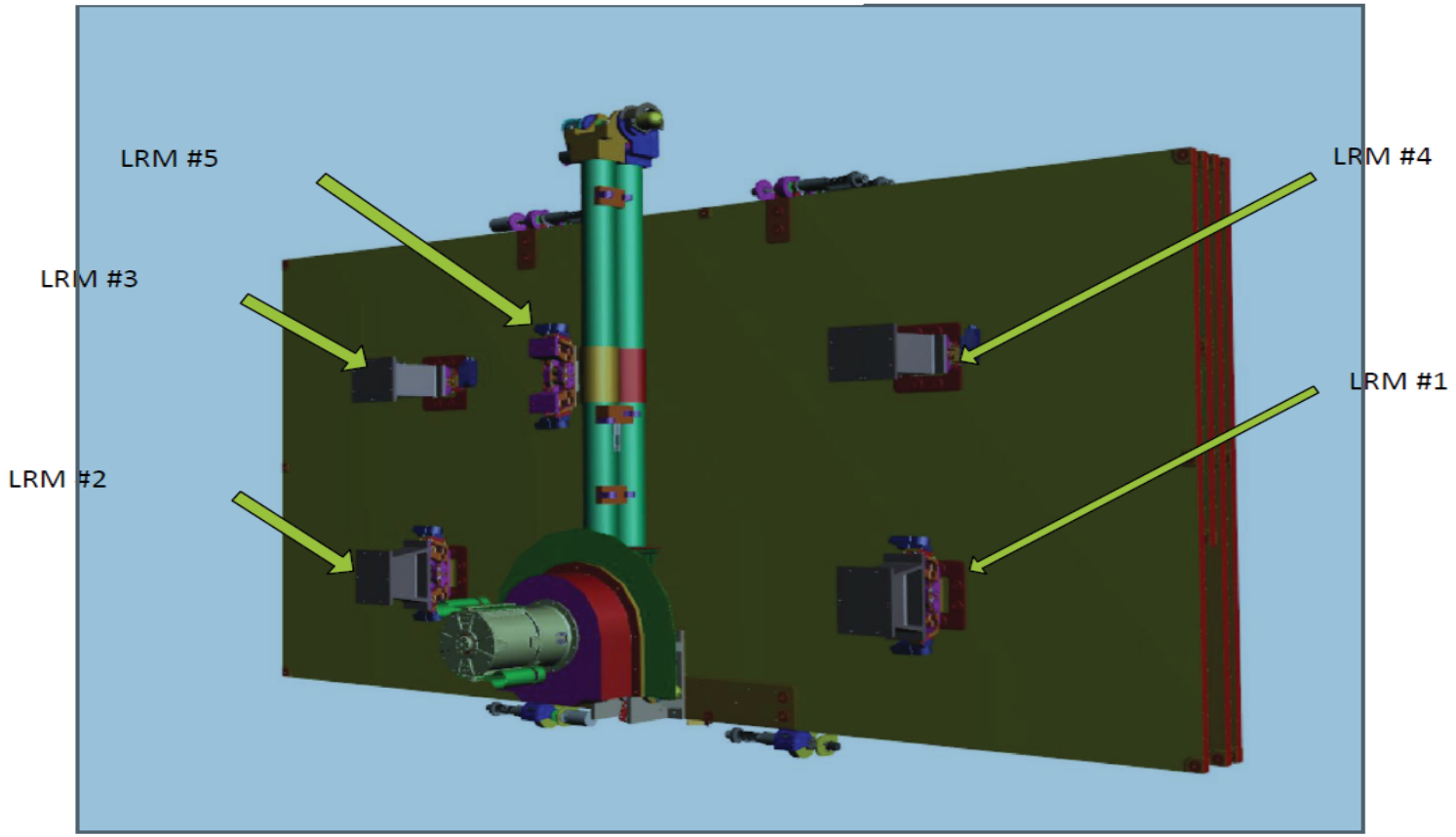
Step1 Define inhibits and controls

Solar Array stowed



LRM- Launch Restraint Mechanism

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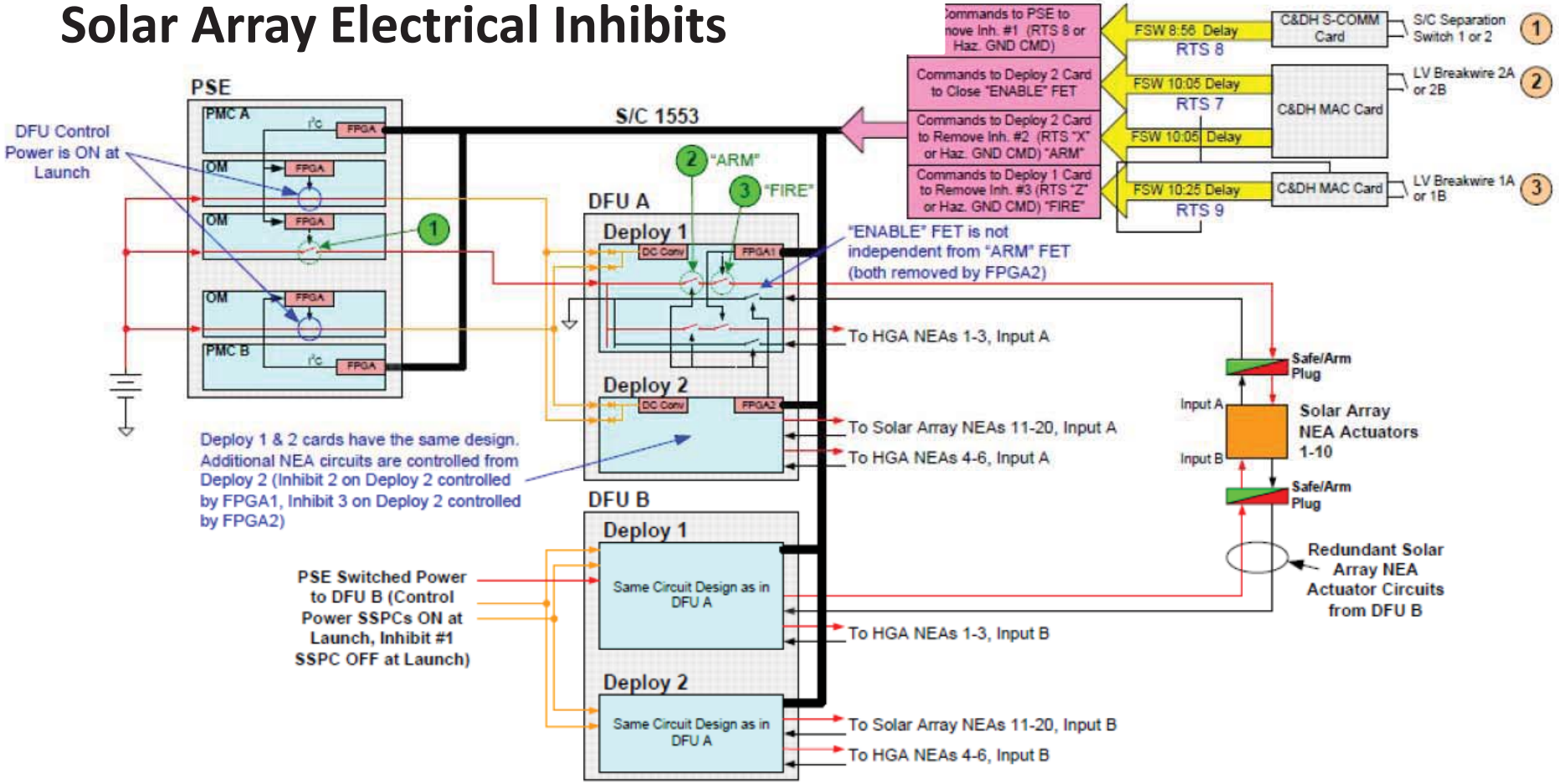
Step1 Define inhibits and controls

Solar Array Electrical Inhibits

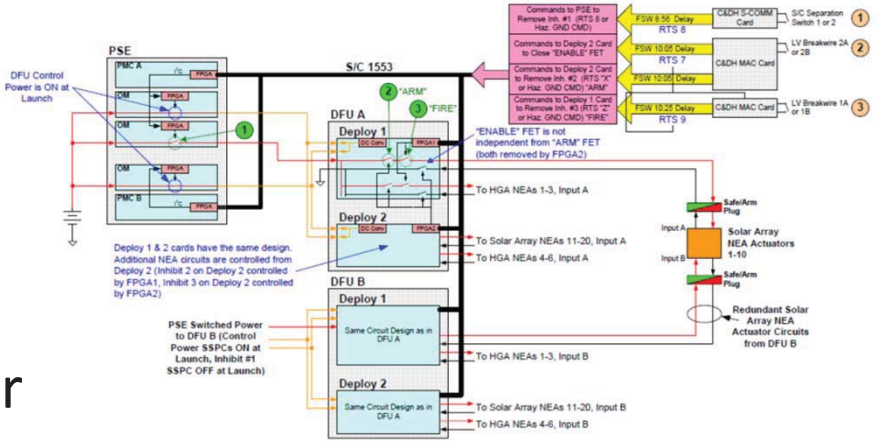


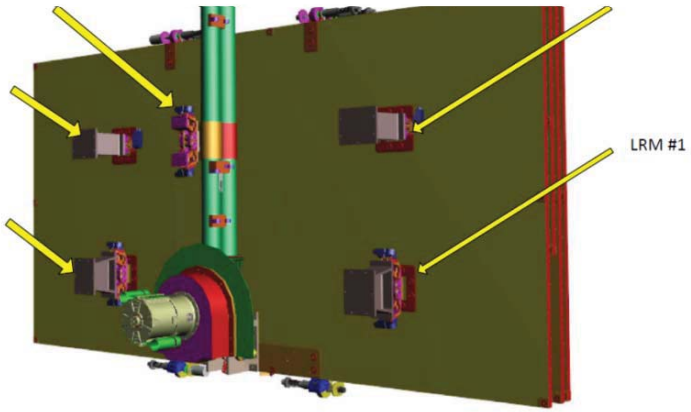
DFU-Deployment Firing Unit
PSE- Power Supply Electronics
NEA-Non-Explosive Actuators

Step1 Define inhibits and controls

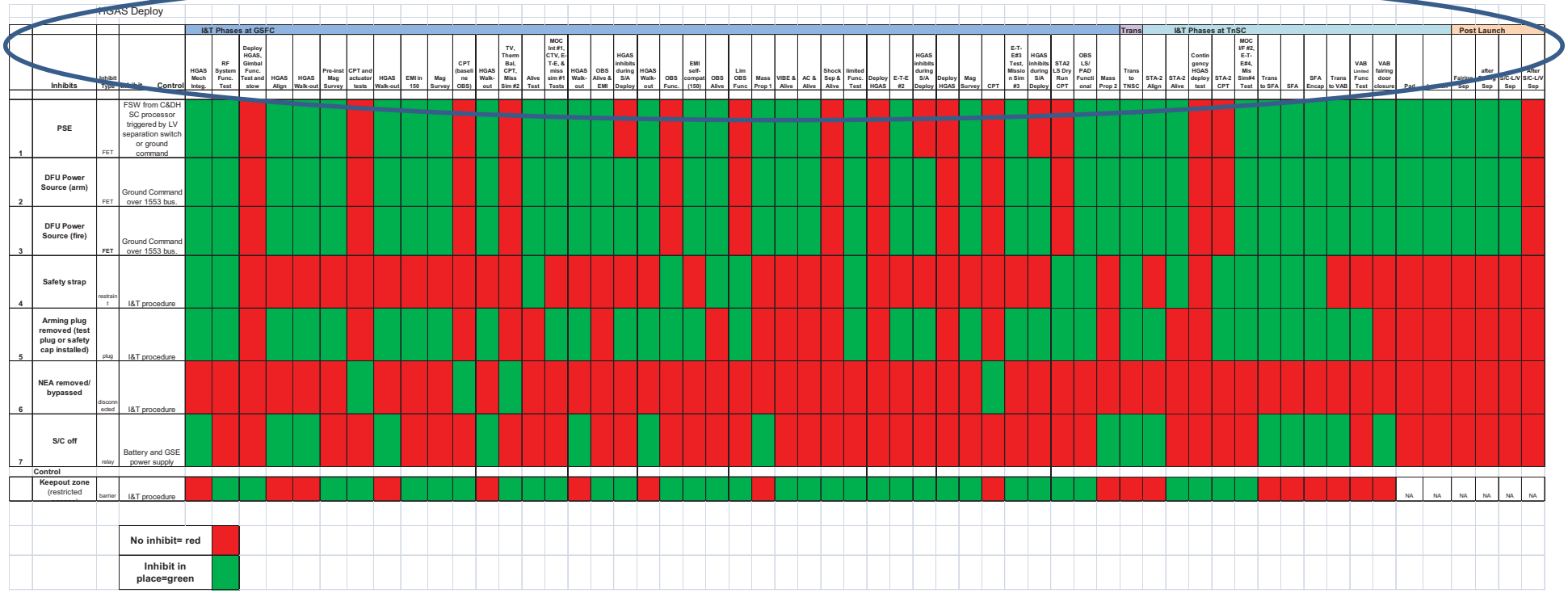
Solar Array Inhibits and Controls

- Solar array (red is the difference with HGAS)
  - Mechanically (5) Deployment hinges
  - Electrically it is 2-fault tolerant for each hinge
  - Inhibits include:
    1. FET in Power Systems Electronics
    2. 1st FET in Deployment Firing Unit
    3. 2nd FET in Deployment Firing Unit
    4. Power relay switch off
    5. Tether/pin
    6. Arming plug removed
    7. NEA's are either removed or by-passed
    8. Keepout zone





Step 2 Define I&T testing



Step 2 Define I&T testing

- Performance Tests
  - CPT Comprehensive Performance Test
  - Functional test
  - Aliveness test
  - Alignment test
  - Mass properties
  - Magnetic Survey
  - End-to-End/MOC test
  - Deployment test and stow
  - Walkout test and stow
- Environmental Testing
  - Thermal Vacuum/Thermal Balance
  - EMI tests
  - Vibration tests
  - Acoustics test
  - Shock Separation test

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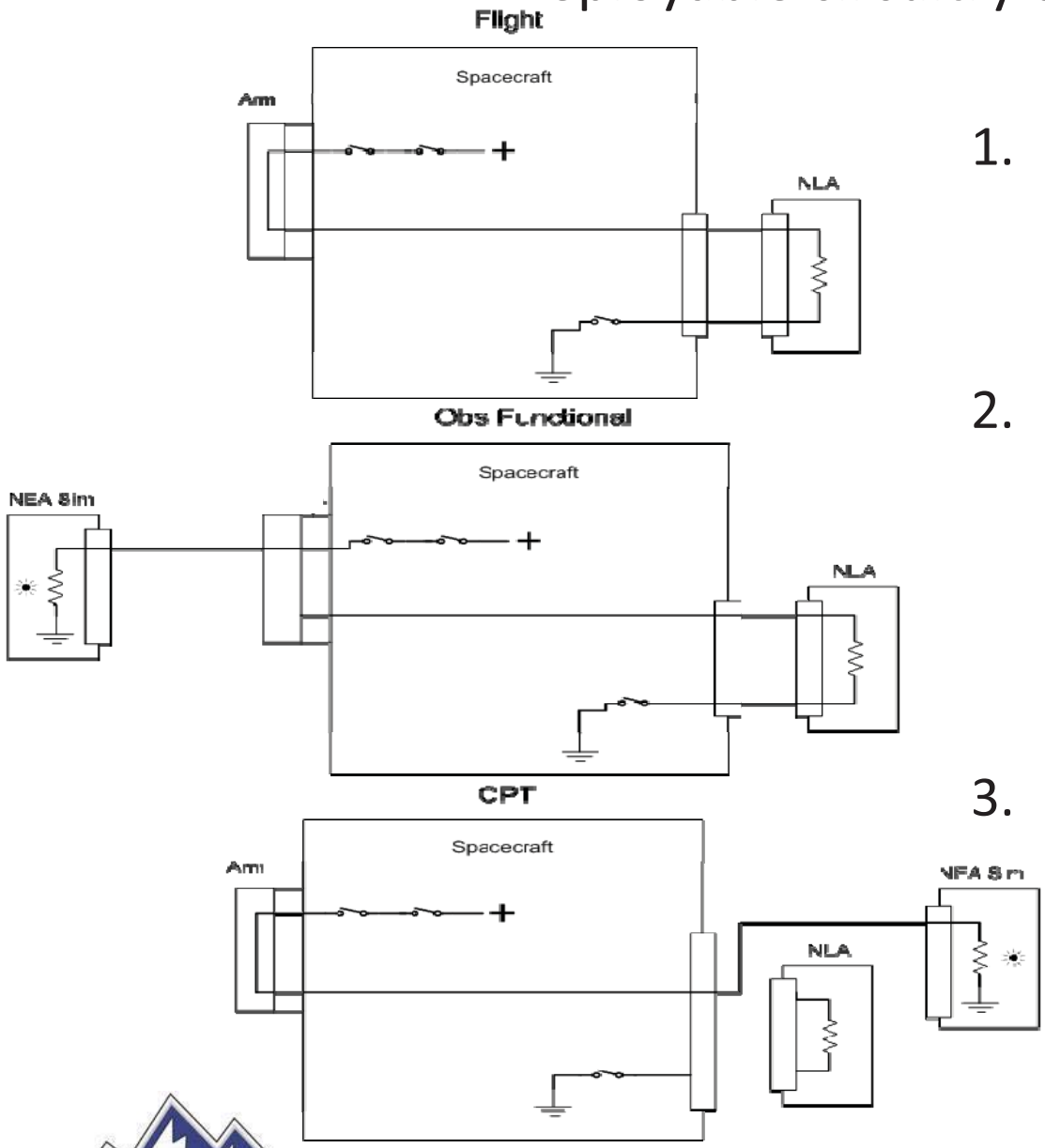
Step 2 Define I&T testing

Deployable circuitry during testing



1. Top figure is the operational configuration of the NEA in place with 3 inhibits and arming plug. Functional test.
2. Middle figure is the Observatory functional test. Power to the box. For deployables, arming plug removed and NEA simulator used so NEA's won't fire.
3. Bottom is the CPT test. (comprehensive performance test). Arming plug in place but NEA's electrically disconnected.

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Step 2 Define I&T testing

- Performance Tests
  - CPT Comprehensive Performance Test
  - Aliveness test
  - Functional test
  - Alignment test
  - Mass properties
  - Magnetic Survey
  - End-to-End/MOC test
  - Deployment test
  - Walkout test
- Environmental testing
  - Thermal Vacuum/Thermal Balance
  - EMI tests
  - Signal injection (DPR specialty test)
  - Vibration tests
  - Acoustics test
  - Shock Separation test

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Step 2 Define I&T testing –

Test order on GPM Timeline Tool

1 Mechanical Integration for each subsystem

2 Deploy HGAS, Gimbal Func. Test and **stow**

3 HGAS Align

4 HGAS Walk-out

5 Pre-inst **Mag Survey**

6 CPT and actuator tests

7 HGAS Walk-out

8 Mag Survey

9 CPT (baseline OBS)

10 HGAS Walk-out

11 TV, Therm Bal, CPT, Miss Sim #1

12 Aliveness Test

13 MOC Int #1, CTV**, E-T-E**, & miss sim #2 Tests

14 HGAS Walk-out

15 OBS Aliveness & EMI

16 S/A Deploy

17 HGAS Walk-out

18 OBS Functional Test

19 OBS **Aliveness Test**

20 Limited OBS **Functional Test**

21 Mass Properties

22 Vibration & Aliveness Test

23 Acoustics & Aliveness Test

24 Shock Separation & Aliveness Test

25 limited **Functional Test**

26 Deploy HGAS

27 E-T-E #2

28 Solar Array Deploy

29 HGAS Walk-out

30 Magnetic Survey

31 CPT

32 E-T-E#3 Test, Mission Sim #3

33 **Solar Array Deploy**

34 STA2 LS Dry Run **CPT**

35 OBS LS/ PAD **Functional Test**

36 Mass Properties #2

37 Transfer to Launch Site

38 Alignment test

39 Aliveness test

40 Contingency **HGAS deploy test**

41 Contingency **Solar Array deploy test**

42 CPT

43 MOC I/F #2, E-T-E #4, Mis Sim#4 **Test**

44 Fueling

45 Encapsulation

46 Limited **Functional Test**

47 Launch

48 Fairing Separation

49 Launch Vehicle Separation

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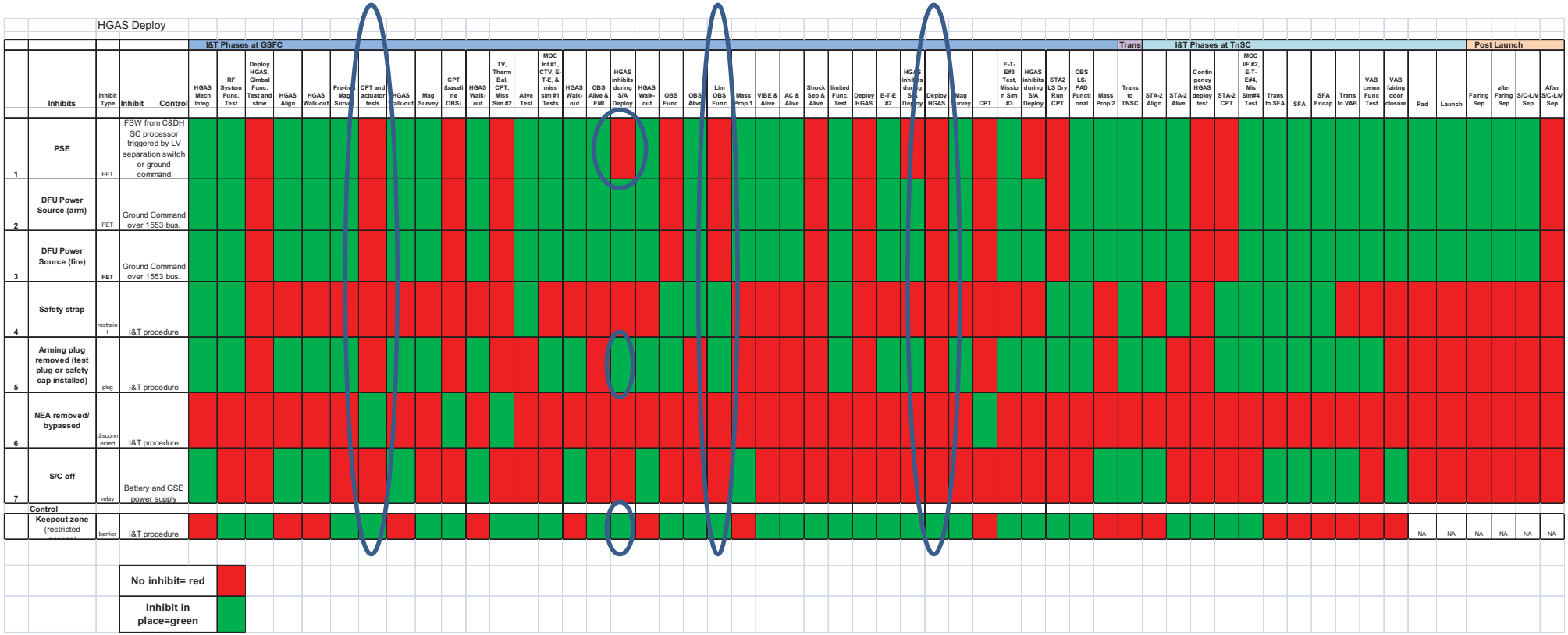
Step 3 Determine Inhibit status During Each Test – High Gain Antenna Deploy



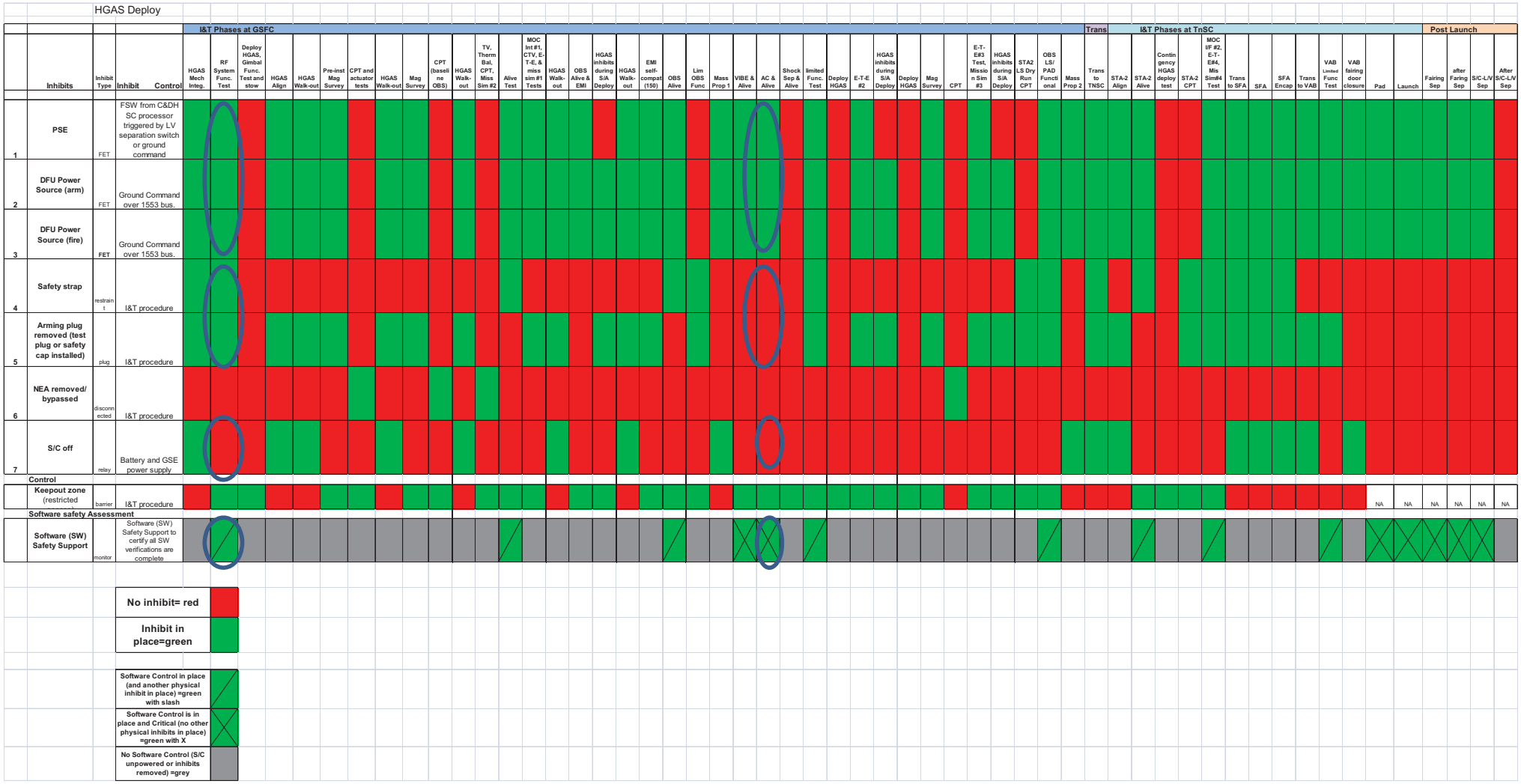
Step 3 Determine Inhibit status During Each Test - Solar Array Deployment

Solar Array Deploy

				I&T Phases at GSFC																							Trans	I&T Phases at TnSC													Post Launch			
	Inhibits	Inhibit Type	Inhibit Control 1	Func. Test	EMI	Mag Survey	CPT	TV Therm Bal	Alive Test	End-to-End Test	EMI	Integrate and Deploy SA, Alive test, SA stow	Mass Prop 1	VIBE & Alive	AC & Alive	Shock Sep & Alive	limited Func. Test	E-T-E #2	Integrate, Deploy SA, Alive test, SA stow, deintegrate	Mag survey	CPT	E-T-E#3 Test, Mission Sim #3	Integrate and Deploy SA, Alive test, SA stow	STA-2 LS Dry Run CPT	OBS LS/ PAD Functional	Mass Prop 2	Trans to TNSC	STA-2 Align	STA-2 Alive	Contingency SA deployment test	STA-2 CPT	MOC I/F #2, E-T-E#4, Mis Sim#4 Test	Trans to SFA	SFA	SFA Encap	Trans to VAB	VAB Limited Func Test	VAB fairing door closure	Pad	Launch	Fairing Sep	after Faring Sep	S/C-L/V Sep	S/C-L/V Sep plus 9.75 min
1	PSE to deployment	FET	FSW from C&DH SC processor triggered by LV separation switch or ground command	NA	NA	NA	NA	NA	NA	NA	NA							NA		NA	NA	NA																						
2	DFU Power Source (arm)	FET	FSW from C&DH SC processor triggered by LV separation breakwires or ground command	NA	NA	NA	NA	NA	NA	NA	NA							NA		NA	NA	NA																						
3	DFU Power Source (fire)	FET	FSW from C&DH SC processor triggered by LV separation breakwires or ground command	NA	NA	NA	NA	NA	NA	NA	NA							NA		NA	NA	NA																						
4	tether/pin	restraint	I&T procedure	NA	NA	NA	NA	NA	NA	NA	NA							NA		NA	NA	NA																						
5	Arming plug removed (test plug or safety cap installed)	plug	I&T procedure	NA	NA	NA	NA	NA	NA	NA	NA							NA		NA	NA	NA																						
6	NEA removed/ bypassed	disconnected	I&T procedure	NA	NA	NA	NA	NA	NA	NA	NA							NA		NA	NA	NA																						
7	S/C off	relay	Battery and GSE power supply	NA	NA	NA	NA	NA	NA	NA	NA							NA		NA	NA	NA																						
	Control																																											
	Keepout zone (restricted access)	barrier	I&T procedure	NA	NA	NA	NA	NA	NA	NA	NA							NA		NA	NA	NA																	NA	NA	NA	NA	NA	NA

No inhibit= red	
Inhibit in place=green	

Step 4 Determine Software Criticality -HGAS Deployment



Step 4 Determine Software Criticality- Solar Array Deployment

Solar Array Deploy

				I&T Phases at GSFC																			Trans	I&T Phases at TnSC														Post Launch			
	Inhibits	Inhibit Type	Inhibit Control 1	Func. Test	Mag Survey	CPT	TV Therm Bal	Alive Test	End-to-End Test	EMI	Integrate and Deploy SA, Alive test, SA stow	Mass Prop 1	VIBE & Alive	AC & Alive	Shock Sep & Alive	limited Func. Test	E-T-E #2	Integrate, Deploy SA, Alive test, SA stow, deintegrate	Mag survey	CPT	E-T-E#3 Test, Mission Sim #3	Integrate and Deploy SA, Alive test, SA stow	STA-2 LS Dry Run CPT	OBS LS/ PAD Functional	Mass Prop 2	Trans to TNSC	STA-2 Align	STA-2 Alive	Contingency SA deployment test	STA-2 CPT	MOC I/F #2, E-T-E#4, Mis Sim#4 Test	Trans to SFA	SFA	SFA Encap	Trans to VAB	VAB Limited Func Test	VAB fairing door closure	Pad	Launch	Fairing Sep	after Faring Sep	S/C-L/V Sep	S/C-L/V Sep plus 9.75 min
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2	DFU Power Source (arm)	FET	FSW from C&DH SC processor triggered by LV separation breakwires or ground command	NA	NA	NA	NA	NA	NA	NA							NA		NA	NA	NA																					
3	DFU Power Source (fire)	FET	FSW from C&DH SC processor triggered by LV separation breakwires or ground command	NA	NA	NA	NA	NA	NA	NA							NA		NA	NA	NA																					
4	tether/pin	restraint	I&T procedure	NA	NA	NA	NA	NA	NA	NA							NA		NA	NA	NA																					
5	Arming plug removed (test plug or safety cap installed)	plug	I&T procedure	NA	NA	NA	NA	NA	NA	NA							NA		NA	NA	NA																					
6	NEA removed/ bypassed	disconnected	I&T procedure	NA	NA	NA	NA	NA	NA	NA							NA		NA	NA	NA																					
7	S/C off	relay	Battery and GSE power supply	NA	NA	NA	NA	NA	NA	NA							NA		NA	NA	NA																					
	Control																																										
	Keepout zone (restricted access)	barrier	I&T procedure	NA	NA	NA	NA	NA	NA	NA							NA		NA	NA	NA																	NA	NA	NA	NA	NA	NA
	Software safety Assessment																																									
	Software (SW) Safety Support	monitor	Software (SW) Safety Support to certify all SW verifications are complete	NA	NA	NA	NA	NA	NA	NA							NA		NA	NA	NA																					

No inhibit= red	
Inhibit in place=green	
Software Control in place (and another physical inhibit in place) =green with slash	
Software Control is in place and Critical (no other physical inhibits in place) =green with X	
No Software Control (S/C unpowered or inhibits removed) =grey	

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Step 4 Determine Software Criticality - GMI Deployment

Step 4 Determine Software Criticality - S/C Transmitter Activation

S/C RF Transmitters

	Inhibits	Inhibit Type	Inhibit Control for Transmitter B Omni	Inhibit Control for Transmitter A HGA and Backup GND commands for Transmitter B	I&T Phases at GSFC: Func. Test	Mag Survey	CPT (baseline OBS)	TV, Therm Bal, CPT, Miss Sim #2	Alive Test	MOC Int #1, CTV, E-T-E, & miss sim #1 Tests	OBS Alive & EMI	Func. Test	Alive Test	Func. Test	Mass Prop 1	VIBE	Alive test (stowed)	AC	Alive test	Shock Sep & Alive	Limited Func. Test	E-T-E #2	Mag Survey	CPT	E-T-E#3 Test, Mission Sim #3	STA2 LS Dry Run CPT	OBS LS/ PAD Functional	Mass Prop 2	Trans: Trans to TNSC	I&T Phases at TnSC: STA-2 Align	STA-2 Alive	STA-2 CPT	MOC I/F #2, E-T-E#4, Mis Sim#4 Test	OBS LS/ PAD Functional	Trans to SFA	SFA	SFA Encap	Trans to VAB	VAB Limited Func Test	VAB fairing door closure	Pad	Launch	Post Launch: Fairing Sep	approx 370 sec after Faring Sep
1	PSE 1 to transmitter	FET	FSW from C&DH SC processor over 1553 bus triggered by fairing breakwires plus timer	Ground Command over 1553 bus																																								
2	PSE 2 to transmitter	FET	FSW from C&DH SC processor over 1553 bus triggered by fairing breakwires plus timer	Ground Command over 1553 bus																																								
3	Transponder	FET	FPGA from C&DH via 422 initiated by FSW triggered by T-01 or T-02 breakwires plus timer	Ground Command over 1553 bus																																								
4	Hat couplers	absorber	I&T procedure	I&T procedure																																								
5	S/C off	relay	Battery and GSE power supply	Battery and GSE power supply																																								
Control	Keepout zone	barrier	I&T procedure	I&T procedure																																					NA	NA	NA	NA
Software safety Assessment	Software (SW) Safety Support	monitor	Software (SW) Safety Support to certify all SW verifications are complete	Supporing Hazard Inhibits/Contr																																								

No inhibit= red	
Inhibit in place=green	
Software Control in place (and another physical inhibit in place) =green with slash	
Software Control is in place and Critical (no other physical inhibits in place) =green with X	
No Software Control (S/C unpowered or inhibits removed) =grey	

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Step 4 Determine Software Criticality - DPR Radar Activation

RF (Ku PR and/or Ka PR)

Step 4 Determine Software Criticality - Propulsion Hydrazine Release

Propulsion Inhibits

				I&T Phases at GSFC																						Trans	I&T Phases at TnSC											Post Launch			
	Inhibits	Inhibit Type	Inhibit Control	Func. Test	Mag Survey	CPT (baseline OBS)	TV, Therm Bal, CPT, Miss Sim #2	Alive Test	MOC Int #1, CTV, E-T-E, & miss sim #1 Tests	OBS Alive & EMI	Func. Test	Alive Test	Func. Test	Mass Prop 1	VIBE & Alive	AC & Alive	Shock Sep & Alive	limited Func. Test	E-T-E #2	Mag Survey	CPT	E-T-E#3 Test, Mission Sim #3	STA2 LS Dry Run CPT	OBS LS/ PAD Functional	Mass Prop 2	Trans to TNSC	STA-2 Align	STA-2 Alive	STA-2 CPT	MOC I/F #2, E-T-E#4, Mis Sim#4 Test	Trans to SFA	SFA Fueling	SFA Encap	Trans to VAB	VAB Limited Func Test	VAB fairing door closure	Pad	Launch	Fairing Sep	after Faring Sep	S/C-L/V Sep	After S/C-L/V Sep
1	PSE PROP I/O	FET	Ground command to PSE	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA											
2	MACE A power source (Latch and Thruster)	FET	Ground command to PSE for MACE A PROP I/O FPGA 1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA											
3	MACE A return (Latch and Thruster)	FET	Ground command to PSE for MACE A PROP I/O FPGA 2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA											
4	S/C off	relay	Battery and GSE power supply	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA											
	Control																																									
	Keep out zone (operators in SCAPE)	barrier	I&T procedure	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA								NA	NA	NA	NA	NA
	Software safety Assessment																																									
	Software (SW) Safety Support	monitor	Software (SW) Safety Support to certify all SW verifications are complete	NA	NA	NA	N/A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	N/A	NA	NA	NA	N/A	N/A	N/A	N/A	N/A											

No inhibit= red	
Inhibit in place=green	
Software Control in place (and another physical inhibit in place) =green with slash	
Software Control is in place and Critical (no other physical inhibits in place) =green with X	
No Software Control (S/C unpowered or inhibits removed) =grey	

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Unique Hazard Report Controls for Software

Inadvertent Commanding via Ground or Flight Software

1. Safety critical commands and telemetry database for the C&DH flight software and ground systems loaded with configured database (ASIST) operates properly.
2. Restrict the use of safety critical software that removes deployment inhibits commands to one per flight command sequence (script).
3. NASA software safety will review build test plans and results used to test the loaded flight image to ensure full coverage of safety critical functions.
4. The flight software will require three independent “signals” following independent software and hardware paths to remove the three independent safety inhibits.
5. Monitor health and safety of flight software system. The safety critical functionality is listed below:
   a) Hardware memory scrubbing
   b) Routine which detects faulted tasks (Health and Safety task)
   c) Hardware which detects faulted tasks (Health and Safety task)
   d) Flight processor watchdog timer
   e) Background checksum
   f) Verify initial flight command sequence (i.e. Tables)
6. Prohibit safety critical commands from the ground system from post encapsulation through planned L/V separation. (Flight Rule).
7. The on board memory will be protected against memory errors by incorporating a memory scrubbing routine that will correct single bit errors (via hardware) and report multi bit errors.
8. The on board flight software will require double checking telemetry values (persistency check) before executing on board scripts (capable of removing safety inhibits).
9. If the redundant processor is activated it boots using a certified flight image (flight SW image and tables).
10. NASA will provide independent analyses of flight code.

Agenda

- Scope of Discussion
- Motivation for Creation of the Tool
- Definition of Terms
- GPM Overview
- Tool Development Process Steps
  - Step 1 Define Inhibits and controls
  - Step 2 Define I&T testing
  - Step 3 Determine inhibit status during each test
  - Step 4 Determine software criticality
- Unique Hazard Report Controls and Verifications for Software
- Summary

Summary

1. I&T is complicated and safety inhibit philosophy can be different from test to test.
2. Software criticality depends on testing's use of the hardware inhibits.
3. Tool helped Safety bridge a gap of understanding of the I&T testing plans
    - Allowed the safety team to make a more informed decision on use of inhibits and a summary of what needed to be in the WOA's/procedures. Time savings when reviewing procedures.
    - Provided a communication tool with Systems Engineers and Project Management. Was able to point out inconsistencies, potentials risks and hazards.
4. Tool can be used on other missions for the same purpose.

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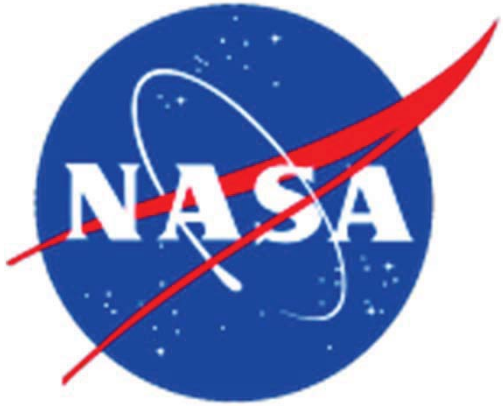
全球降水観測計画
GPM
GLOBAL PRECIPITATION MEASUREMENT

THANK YOU!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Questions?

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THANK YOU VERY MUCH!!

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